CHAPTER 17
DISINFECTION

17-1. General considerations.

Disinfection is a process in which pathogenic organisms are destroyed or inactivated. This process may be accomplished by physiochemical treatment or addition of chemical reagents. Improved coliform and virus removal can be obtained by utilizing flash mixing and acid feed for pH reduction. Chlorine, as liquid chlorine or in the form of chlorine compounds, is the most common chemical used to disinfect wastewater treatment plant effluents. Calcium hypochlorite or sodium hypochlorite will only be used as chlorinating agents for very small installations (less than 0.02 million gallons per day). Ozone has been an effective disinfectant when used in the water treatment field and its use as a disinfectant for wastewater is being seriously considered. This interest has developed mainly because zonated effluents have normally shown no toxic effects on the receiving water biota as have residual chlorine compounds; however, for certain industrial wastes, epoxides have been found. The major disadvantage of ozonation is the high capital and operational cost associated with its generation.

17-2. Chlorination.

a. Purposes of chlorination. It is recommended that unless dechlorination is required, chlorine or chlorine derivatives be used for disinfection of wastewater. The principal purposes of wastewater chlorination include:

(1) Disinfection of primary, secondary, and advanced or tertiary plant effluent.

(2) Oxidation of ammonia and organic matter contribution to biochemical oxygen demand.

(3) Destruction and control of iron-fixing bacteria and slime-forming bacteria.

(4) Destruction and control of filter flies and slime growth on trickling filters.

(5) Control of septic conditions and resulting odors.

(6) Control of algae and related organisms.

It should be noted that chapter 14 of this manual provides a detailed discussion on chlorination of waste pond effluent since pond effluent has unique chlorine demand requirements. The discussion in this chapter should complement that in chapter 14.

b. Limitations of chlorine. Although chlorine is an effective disinfectant when in actual contact, the chlorine may not always come in contact with the microorganisms that are inside the organic matter. There is a danger of a false security, which prevails among the general public (and, to some extent, among engineers and plant operators), in the impression that chlorine will remove all health hazards from wastewater. Chlorine disinfection involves a very complex series of events and is influenced by the kind and extent of reactions with chlorine-reactive materials, temperature, pH, suspended solids concentrations, and the viability of test organisms. It is essential that the design of the various elements of the treatment plant be such that effective treatment will reduce the need for disinfection to a minimum. Both coliform and virus removal can be improved over conventional practices by acid feeding to reduce the pH to between 5.3 and 5.8 and by providing flash mixing of the chlorine and wastewater.

c. Design parameters. EPA guidelines for chlorination of wastewater treatment plant effluent require a detention period of 30 minutes in the contact chamber to provide maximum disinfection. Table 17-1 should be used to estimate chlorine dosage requirements.

Table 17–1. Typical chlorine dosages required for sewage disinfection.

Type of effluent to be disinfected	Dosage mg/L	Dosage lb/mil gal
Raw wastewater	20	167
Raw wastewater (septic)	50	420
Settled wastewater	20	167
Settled wastewater (septic)	40	354
Chemical precipitated effluent	15	126
Trickling filter effluent	15	127
Activated sludge effluent	8	67
Sand filter effluent	6	50

d. Use of hypochlorite. The use of hypochlorite compounds such as calcium hypochlorite and sodium hypochlorite as a substitute for chlorine gas is usually justifiable for very small installations. Sodium hypochlorite solution normally provides 12.5 percent available chlorine, and calcium hypochlorite solution normally provides 65 percent available chlorine. To determine the equivalent dosages required for these chemicals if used to disinfect the various types of effluents described above, divide the dosage figures by the fraction of available chlorine attributable to the specific chlorine compound. Sodium hypochlorite is available in solution form and calcium hypochlorite is available in solid form. Both calcium and sodium hypochlorite shall be stored in cool, dry locations in corrosion-resistant containers.

e. Other chlorine uses. Chlorination of wastewater can reduce its biochemical oxygen demand by 15 to 35 percent; this is a common practice to relieve overloaded plants until additional capacity is provided. Approximately 2 milligrams per liter of biochemical oxygen demand can be removed by 1 milligram per liter of chlorine up to the point at which residual chlorine is produced. Odor control can be achieved by prechlorination doses of 4 to 6 milligrams per liter. Odors from sludge drying beds can be reduced by applying calcium hypochlorite at a rate of ½ pound per 100 square feet of bed area. Periodic application of chlorine in trickling filter influent will reduce filter clogging and ponding. A chlorine dose of 1 to 10 milligrams per liter, based on the returned sludge flow, is sometimes required for control of bulking sludge in an activated sludge process. A chlorine residual of 1 milligram per liter in sludge thickener supernatant prevents sludge from becoming septic during its holding period.

f. Mixing. Rapid mixing at the point of chlorine application is critical for disinfection efficiency, while adequate mixing at the same point is critical for control puposes (see G.C. White, Handbook of Chlorination). The following methods are acceptable mixing practices to be used at military installations: hydraulic jump, submerged weir, over-and-under baffle, mechanical mixer, and closed conduit flowing full with adequate turbulence. The design of the system should provide for addition of chlorine solution through a diffuser, which may be a plastic or hard rubber pipe with drilled holes through which the chlorine solution can be uniformly distributed into the path of flow of sewage; or it can flow directly to the propeller of a rapid mixer for instantaneous and complete diffusion. Mixing by hydraulic turbulence for at least 30 seconds must be maintained at or near the point of addition of chlorine solution to the sewage if mechanical mixing is not used.

17-3. Chlorine feeding equipment.

The chlorinator capacity will be designed to have a capacity adequate to provide the dosage requirement stipulated in paragraph 17-2c at maximum flow conditions. Standby equipment of sufficient capacity will be provided to replace the largest unit during shutdowns. Design considerations will be based on the assumption that chlorine can be vaporized from 150-pound cylinders at a rate of 40 pounds per 24 hours, 30 pounds per 24 hours from 105-pound cylinders, and 450 pounds per 24 hours from 1-ton cylinders. Where greater rates of feed are required, a suitable number of containers will be manifolded unless facilities are installed to prevent chlorine system freezing due to evaporation. The use of 1-ton cylinders will be used where the average daily chlorine consumption is over 150 pounds.

a. Direct-feed chlorinator. The use of equipment for feeding chlorine gas from the cylinder through a control apparatus to the point of application is not permitted except under special conditions which prevent the use of solution-feed chlorinators.

b. Solution-feed chlorinator. Pressure feed and vacuum feed are, in general, two types of solution feeders. The vacuum-feed type chlorinator is the preferred type, and will be used for all installations where a suitable make-up water supply is available (such as potable water or suitable plant effluent).

c. Hypochlorite feeders. These feeders are of the mechanical, positive-displacement metering type and their use will be limited to installations designed for the addition of hypochlorite solution. All plants with flows of 0.02 million gallons per day or less will use this method of chlorination.

d. Scales. Scales will be sized to accommodate the maximum number of cylinders required to serve the maximum chlorine rate. They may be mounted flush with the floor or on the floor surface within an enclosing box. With above-floor mounting, overhead hoist equipment must be considered. Flush-mounted scales will require drainage of the scale sump. A loss-of-weight recorder is desirable to provide a continuous record of chlorine feed.

e. Electric hoisting equipment. Electric hoisting equipment will be provided for installation, using 1-ton cylinders. Hoists will have a minimum capacity of 2 tons and will be equipped with an approved type of lifting-beam container grab.

f. Piping. Only pipe and materials approved by the manufacturers of chlorine equipment will be used in chlorine installations. Piping and valves will be color coded.

g. Housing.

(1) **Room separation.** If chlorinators or cylinders are in a building used for other purposes, a gas-tight partition will separate the chlorine room from any other portion of the building. Doors to the room will open only to the outside of the building and will be equipped with panic hardware. The storage area will be separated from the feed area.

(2) **Inspection window.** A clear glass, gas-tight window will be installed in an exterior door or interior wall of the chlorinator room to permit the chlorinator to be veiwed without entering the room.

(3) **Heat.** Chlorine equipment rooms will be provided with a means of heating so that a room temperature of at least 60 degrees Fahrenheit can be maintained. This will help to prevent the formation of chlorine hydrate in the chlorinator.

(4) **Ventilation.** Forced mechanical ventilation, which will provide one complete air change every 3 minutes, will be installed. The entrance to the air exhaust will be located so as not to contaminate the air inlet to any building or inhabited areas. air inlets will be located to provide cross-ventilation. Th prevent a fan from developing a vacuum in the room, thereby making it difficult to open the doors, louvers should be provided above the entrance door and opposite the fan suction. Where duct work is required to carry air to the fan, it should be laid out so that the suction openings are at floor level and spaced so as to exhaust air from all equipment areas. Exhaust openings should be designed so that covers are not required.

(5) **Electrical controls.** A common control for the fans and lights, keyed to an exterior lock on the entrance door so that they will automatically come on when the door is opened; will only be deactivated by relocking the door externally; and can also be manually operated from the outside without opening the door. An interlock between the entrance door lock and the exhaust fan should be installed so that the fan will be actuated when the door is unlocked.

(6) **Cylinder storage.** A storge area will be provided to allow for a minimum 15-day inventory of reserve and empty cylinders. Cylinders may be stored outdoors on suitable platforms at or above grade under cover in a well-ventilated, fireproof structure.

(7) **Precautions in the use of chlorine.** The presence of chlorine gas in the atmosphere can pose immediate and serious hazards to the health of any person breathing the air. Gas masks approved by the National Institute of Occupational Safety and Health (NIOSH) will be provided outside any area where an individual would be exposed in the event of chlorine leaks, spills, etc. All rooms in which chlorine is to be stored or handled should be adequately ventilated to the outside. A fan which automatically turns on prior to entry into the chlorination or storage facility will be provided. Since chlorine gas is heavier than air, vent outlets will be placed at floor level. Chlorine detectors of the liquid reagent, electrode cell, indicating meter type, sensitive to one part per million O)y volume) chlorine in the air, will be used to continuously monitor the air for chlorine leaks. Alternatively, the enclosed space should be entered only if the worker is under observation by a co-worker and if the worker has in his possession a respirator suitable for escape. The applicable safety recommendations, as given in the American Water Works Association (AWWA) publication, Safety **Practice for Water Utilities,** and Water Pollution Control Federation (WPFC) Manual of Practice No.1, **Safety in Wastewater Works,** should be followed. Information on the properties of chlorine and its safe handling are also available from the Chlorine Institute. When hypochlorite compounds and generators are used, the above requirements do not apply.

h. Chlorine generators. Units are commercially available for generating sodium hypochlorite. These may be used for the source of chlorine at facilities where an ample supply of brine solution or salt water is readily available or can be readily mixed. Such systems should be evaluated in accordance with requirements of chapter 5 of this manual when design analysis confirms that, technically, they are equal to or better than alternate chlorine sources. Design must include adequate facilities for safely handling the hydrogen gas released in the generating process.

i. Chlorine contact chambers. A chlorine mixing contact chamber will be designed to provide a minimum of 30 minutes detention time at the peak design flow. Consideration will be given to two flow-through units with common-wall construction so that each side satisfies the detention requirements. The ability to segregate each side for cleaning purposes will be included. Short circuiting will be minimized with inlet baffles and end-around baffling within the tank. A minimum length-to-width ratio of 40 to 1 should be utilized. The chlorine feed rate will be proportioned in accordance with the flow and the chlorine demand of the wastewater. Adequate mixing during the chlorine contact period will be insured by the installation of adequate baffling, or by either mechanical or air mixing.

j. Chlorine control equipment. Residual chlorine in the plant effluent must meet the NPDES permit requirements. Residual chlorine analyzers are required for all plants using chlorine gas. Maintaining a consistent chlorine residual in the related wastewater is the best control for adequate disinfection. Control will be accomplished by the practice of closed-loop chlorination whereby the chlorine metering equipment is controlled by a chlorine residual analyzer downstream from the point of application. The requirement for continuous or intermittent, automated or manual sampling, analyzing and recording will be directed by Federal permit requirements. Chlorinator alarms will be provided to signal either an abnormally high or an abnormally low vacuum in the line between the chlorinator and the injector.

17-4. Dechlorination.

Dechlorination is the partial or complete reduction of residual chlorine in water by chemical or physical treatment. Disinfection by chlorination will have to be followed by dechlorination to meet NPDES requirements stipulating bacteriological effluent limitations as well as extremely low or zero chlorine concentrations in the final effluent. The theoretical chemical quantities required for dechlorination are given in table 17-2.

Table 17–2. Chemical quantities required for dechlorination.

Dechlorinating Agent	Parts Required Per Part Chlorine Removed
Sulfur dioxide, SO_2	0.90
Sodium bisulfite, NaHSO–*	1.46
Sodium sulfite, NA_2SO_3*	1.77
Hydrogen thiosulfate, $Na_2S_2O_3$	0.70
Hydrogen Peroxide, H_2Os	0.48

* Recommended chemical dechlorinating agents.

a. Sulfur dioxide. Sulfur dioxide is not flammable or explosive in either the gaseous or liquid state but, in the presence of any moisture, it is extremely corrosive. The same materials of construction are used for handling both sulfur dioxide and chlorine. The equipment used to meter sulfur dioxide is identical in all respects to that for metering chlorine. Contact time is not a factor since the dechlorination reaction of sulfur dioxide with chlorine is instantaneous, but rapid and adequate mixing at the point of application is to be provided. The sulfur dechlorinating agents will also reduce dissolved oxygen levels, and re-aeration facilities may have to be provided after the dechlorination step in order to satisfy permit limitation for effluent dissolved oxygen concentrations.

b. Non-chemical methods. Non-chemical means may also be used to accomplish dechlorination. For example, activated carbon used in granular form and a gravity or pressure-type filter bed are extremely effective and reliable. About 0.085 part of activated carbon is needed to remove 1.0 part of chlorine. Retention tanks or ponds may be used for dechlorination purposes but specific design criteria applicable to all domestic wastewaters are not available because the required contact time will depend on the wastewater plus the desired final chlorine residual. Aeration of the final wastewater effluent for the purpose of dechlorination should be seriously considered if the pH of the wastewater is less than 8.0 and the chloramine fraction of the total chlorine residual concentration is less than the total acceptable residual stipulated in the discharge permit.

17-5. Ozonation.

Ozone (O_3) is a particularly powerful oxidizing agent; its immediate viricidal properties are superior to those of chlorine and to a large extent are independent of pH. As a disinfectant, it requires lower dosages and much shorter contact times than chlorine for the same bacterial reductions. Zonated effluents have increased dissolved oxygen concentrations and have less potential for causing a colored effluent. The high capital requirements for ozone generation generally make such systems impractical for wastewater treatment facilities in military installations unless dechlorination is required. Ozonation and other methods of disinfection are covered in detail in: Gehm and Bregman, 1976; Kruse et al., 1973; Bruce et al., 1980; Fair et al., 1966; and Parker and Bregman, 1975.